

Cumulative and Synergistic Effects of Physical, Biological, and Acoustic Signals on Marine Mammal Habitat Use

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LONG-TERM GOALS

The long-term goal of this collaborative research effort is to enhance the understanding of how variability in physical, biological, and acoustic signals impact cetacean habitat use. This is especially critical in areas like the Bering Sea where global climate change can lead to rapid changes of an entire ecosystem. Progressive climate change has the potential to expose areas of the Arctic that have been previously unavailable for civilian and military use. Baseline measurements will play an important role in determining if future military operations are impacting the delicate Arctic ecosystem.

OBJECTIVES

The main objective of this work is to relate synoptic measurements of prey distribution, physical oceanographic process, and sound levels to cetacean habitat use in the Bering Sea. Integrated data such as these will be vital in understanding the relationship between cetaceans and their environment both in the presence and absence of specific noise sources. Long-term measurements will play an important role in determining the point at which cumulative effects of the environment and human activities impact animal populations, and in identifying the kinds of exposure that pose the greatest risk. The Bering Sea is an ecosystem that is presently experiencing rapid climate change, has relatively healthy populations of cetaceans and supports the largest fishery in the US EEZ.

The short-term objectives in Year 1 of this project were to acquire instrumentation for deployment on two NOAA moorings in the Bering Sea, coordinate project and field logistics with all collaborators, develop sampling protocols, and deploy a combined active-passive acoustic system on each of two sub-surface moorings.

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APPROACH

This project is a three-year study involving long-term monitoring of the physical and biological environment at two established NOAA mooring sites (known as M2 and M5) in the Bering Sea (Stabeno and Hunt, 2002). An acoustic monitoring system using both active and passive acoustic sensors will be developed and deployed. The passive component will be used to assess the physical environment and to detect and identify cetaceans present near the moorings. Passive recorders include Passive Aquatic Listeners (PALs) and PMEL recorders (AURALs and/or Haruphones). The PALs are adaptive sub-sampling instruments, whereas the PMEL recorders produce a continuous time series. Comparison of the two datasets will determine what proportion of vocalizations is missed with a sub-sampling protocol and whether an appropriate offset can be developed to compensate for the missed signals. The active component will be used to investigate zooplankton and fish distribution and abundance. The active system includes a three frequency suite of scientific echosounders that will be deployed on each mooring (125 kHz, 200 kHz, and 460 kHz). Ancillary measurements of water column characteristics (current, temperature, salinity, nutrients, ice cover, etc.) will be available from the standard NOAA instrumentation on the moorings. Marine mammal surveys in the area of the moorings will also be available from the NOAA National Marine Mammal Laboratory for groundtruthing of the passive acoustic datasets.

Data analysis will be a multi-step process. Patterns and interactions of measured variables will first be examined within each region according to the following sequence. 1) Datasets generated from the active and passive acoustic sensors will first be analyzed separately to identify specific characteristics and patterns. 2) A series of simple correlation analyses will be performed to identify relationships between cetacean presence and environmental sound parameters, characteristics of physical processes, and prey abundance. 3) An analysis of covariance will be performed to quantify patterns of association between individual parameters. 4) An analysis based on the sorting of blocked data will then be performed to identify interactions between variables and to identify conditions that coincide with high detections of cetaceans. Following the separate analyses in each of the two study regions, observed patterns and factors relating cetacean habitat use will be compared.

Miksis-Olds (APL/PSU) is serving as the overall project coordinator. Miksis-Olds will coordinate all field efforts, lead the active acoustic data analysis, and coordinate dataset integration. Nystuen (APL/UW) is leading the development of PAL sampling algorithms and analysis of PAL data, with the assistance of Miksis-Olds (ARL/PSU). David Mellinger (NOAA/OSU) is coordinating the data collection and preliminary analysis of the PMEL continuous recorders. Mellinger will generate a database of potential detections from the continuous acoustic time series, and a graduate student at PSU will identify the source of the detections. Phyllis Stabeno (NOAA) is providing ship time and personnel to deploy the acoustic sensors at the mooring sites.

WORK COMPLETED

Work completed during Year 1 of this project culminated in the deployment of active and passive acoustic sensors at two mooring sites (M2 and M5) in the Bering Sea in September 2008 (Figure 1). Events leading up to the deployment started with a project planning meeting in Seattle, WA in April 2008. Miksis-Olds, Nystuen, and Stabeno attended the first portion of this meeting where field logistics were discussed for the September mooring cruise aboard the Miller Freeman. The second part of the planning meeting involved Miksis-Olds and Nystuen. Discussion of PAL data analysis techniques and development of sampling algorithms took place.

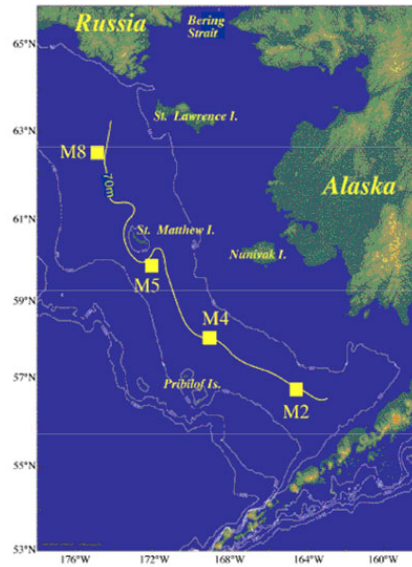


Figure 1. Map showing the location of moorings M2 and M5 on the 70 m isobaths in the Bering Sea.

An associated DURIP award funded the fabrication and acquisition of three PALs and three sets of three-frequency active sensors. Three new PALs are under production at APL/UW (Nystuen) and will be available during Years 2 and 3 of the project. Two existing PALs from APL/UW (Nystuen) have been refurbished and are being used for the initial field deployment in September 2008 by Miksis-Olds. The active sensors (Acoustic Water Column Profiles (AWCPs)) were purchased from ASL Environmental Sciences. Initial field tests of the AWCPs were conducted in June 2008 in Massachusetts Bay. Following the initial field tests, the purchased mooring cages were modified to provide additional stainless steel reinforcement to withstand the harsh conditions in the Bering Sea (Figure 2).

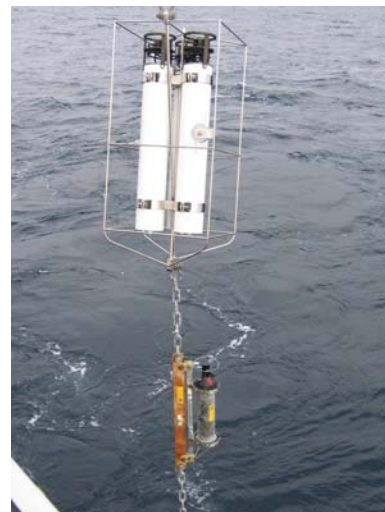


Figure 2. Left: image of three-frequency AWCP trio mounted in reinforced stainless steel mooring cage. Right: image of AWCP sensors and PAL being deployed at mooring site M2.

Deployment of the acoustic sensors took place aboard the NOAA vessel Miller Freeman from Sept 20-30, 2008. On Sept 25, 2008 two moorings were recovered at site M5. A PAL, which had been deployed for a year, was recovered at this site. Data from this instrument will provide information to improve the PAL sampling algorithms on PALs deployed in April 2009. The first set of acoustics sensors was also deployed on this date. The acoustic, sub-surface mooring at site M5 included an ADCP, AWCP sensor package, PAL, AURAL continuous recorder, and an acoustic release (Figure 3). These instruments will be recovered in one year. The sampling protocol for the AWCPs consisted of a 5 minute sampling period every half hour. During the 5 minute sampling period, each frequency would separately sample for one minute totaling 3 minutes. The final two minutes of each sampling period was simultaneous sampling of all three frequencies. Active acoustic sampling by the AWCP sensors and ADCP was staggered to prevent acoustic interference of the two instrument sets. The PAL was programmed to sample and store averaged spectra every 9 minutes as a default. If signals of interest were detected (rain, drizzle, transient vocalizations), a modified sampling protocol was triggered to increase the rate of sampling and record a 4 sec time series. Transient trigger criteria included a +13 dB tonal peak between 800 Hz and 25 kHz.

The acoustic mooring at site M2 was deployed on Sept 29, 2008. This sub-surface mooring included an ADCP, AWCP sensor package, PAL, and acoustic release (Figure 4). Plans were to also include a continuous recorder on this mooring, but the recorder previously deployed on the M2 mooring was not recovered and consequently could not be re-deployed. We plan to deploy a continuous recorder at this site in April 2009 when the instruments at this site are recovered and re-deployed.

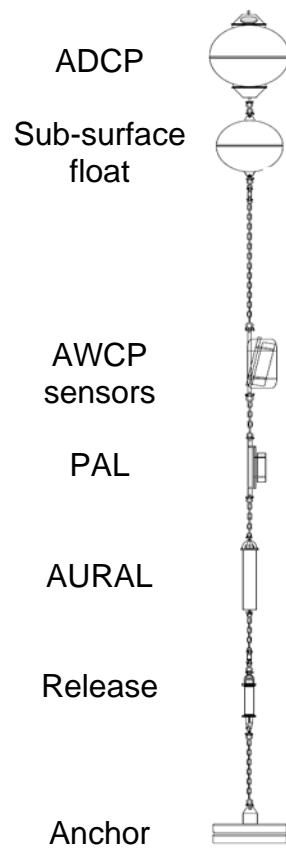


Figure 3. Sub-surface mooring configuration at site M5.

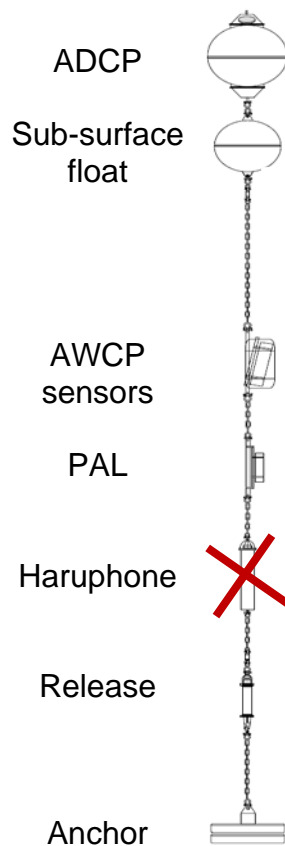


Figure 4. Sub-surface mooring configuration at site M2.
The Haruphone was not included due to a lost mooring.

RESULTS

No results were produced during Year 1 of this project.

IMPACT/APPLICATIONS

The acoustic measurement system used in this project has the advantage of being deployed for long periods of time on subsurface moorings, affording the opportunity to collect valuable data during the harshest conditions of the winter season when traditional sampling techniques are not possible. The combination of year-round acoustic data collected with the active-passive acoustic system, hydrographic data collected by NOAA mooring sensors, and biological samples collected during each research cruise afford the opportunity to apply the acoustics to a large spectrum of scientific questions. Identifying relationships between physical forcing mechanisms, biological activity, and cetacean habitat use will not only be critical in understanding and ultimately predicting how cetaceans respond to noise but also to how ecosystems respond to variability on multiple time scales.

The system used in this study is appropriate for use in almost all marine environments. It provides an advantage over continuous recording instruments in that the initial real-time processing of environmental sound by the PALs detects and identifies sources of interest without an overwhelming

amount of data needing post-processing. The PALs and active acoustic sensors can be programmed to sample at the same time scale to ensure synoptic data collection.

TRANSITIONS

Underwater ambient sound contains quantifiable information about the marine environment, especially sea surface conditions including wind speed, rainfall rate and type, and sea state conditions (bubbles). Furthermore, the presence or absence of sea ice is likely to have distinctive acoustic signature. Mostly this information is unused by oceanographers and the Navy. This project represents a transition from the study of these sounds into the application of the physical and biological interpretation of the sound to provide quantitative assessment of the acoustic marine environment to address a higher level question: What is the effect of changes in the physical marine environment on cetacean use of the habitat? This is a fundamental advance for practical use of passive acoustic monitoring of the underwater marine environment.

RELATED PROJECTS

Combining active and passive acoustics to study marine mammals

PI: Miksis-Olds, ARL PSU

ONR DURIP Award Number: N000140810958

Funds were used to purchase capital equipment used in this study. DURIP funds financed the purchase of 3 PALs and 3 active acoustic systems.

Monitoring sea surface processes using high frequency ambient sound

PI: Nystuen, APL UW

ONR Award Number N00014-04-1-099

The principal goal is to make passive acoustic monitoring of the marine environment an accepted quantitative tool for measuring sea surface conditions (wind speed, rainfall and sea state), monitoring for the presence and identity of marine wildlife (especially whales), and monitoring anthropogenic activities including shipping, sonar and other industrial activities. The new effort described here builds on the research of this ongoing project.

Several NOAA-supported projects, including Passive Acoustic monitoring of killer and beluga whales at the Barren Islands, Alaska, the Bering Sea Acoustic Report, Marine Mammal Monitoring for NW Fisheries, and Monitoring killer whale predation at Stellar Sea Lion rookeries in the Aleutian Islands, use PALs as the principal monitoring instrument for the description of the environment and for the detection and identification of marine cetaceans and other marine animals. This project benefits directly from the data collection strategies and interpretation developed for these projects.

REFERENCES

Staben, P.J. and G.L. Hunt, Jr. 2002: Overview of the Inner Front and Southeast Bering Sea carrying capacity programs. *Deep-Sea Research*: 49(26), 6157–6168